Title
Raptor-mimicking kites for reducing bird damage to wine grapes

Permalink
https://escholarship.org/uc/item/9932206x

Journal
Proceedings of the Vertebrate Pest Conference, 10(10)

ISSN
0507-6773

Authors
Hothem, Roger L.
DeHaven, Richard W.

Publication Date
1982

RAPTOR-MIMICKING KITES FOR REDUCING BIRD DAMAGE TO WINE GRAPES

ROGER L. HOTHEM and RICHARD W. DeHAVEN, Wildlife Biologists, U.S. Fish and Wildlife Service, Dixon Field Station, Denver Wildlife Research Center, 6924 Tremont Road, Dixon, California 95620

ABSTRACT: Preliminary tests in California vineyards during 1979 and 1980 indicated that a raptor-mimicking kite suspended from a helium-filled balloon (kite-balloon or KB) could reduce bird damage to ripening wine grapes. Based on the results of both damage assessments and bird censuses, one KB per hectare, deployed for alternate 1-wk periods, reduced losses caused by birds by about 33% in 1979 and by an average of 48% in 1980 when compared with 1-wk control periods. Habituation by the birds to the KB appeared to reduce its effectiveness over time in 1979, but this problem was reduced in 1980 by regularly changing the KB components and deployment methods. Based on tests conducted in 1981, polyurethane tetroons (PTs) were the longest lasting of four balloons currently available for use in KBs, but in high winds they flew too close to the ground to keep kites aloft. Spherical balloons made of rubber had better flight characteristics but shorter longevity than the PTs. More testing is needed to evaluate the effectiveness of KBs for protecting entire vineyards during whole-season tests and to identify situations where their use may be cost-effective.

INTRODUCTION

Wild birds damage grapes throughout the United States and, based on a questionnaire survey conducted in 1972, they caused at least $4.4 million worth of damage nationwide; probably more than $3.7 million of that was in California alone (Crase et al. 1976). Most (91%) of the grape growers responding to the questionnaire thought that current bird-damage control methods did little good or only stopped some damage, and that new, more effective control measures were needed.

One approach to bird damage control has been to frighten birds from an area by exploiting their innate fear of raptors. To this end, gas balloons (Davis 1974, Feare 1974), tethered live raptors (Davids 1960), falconry (Blokpoel 1976), and raptor models (Brown 1974, Blokpoel 1976) have all been tried. Although a hawk silhouette suspended from a gas-filled balloon was found to be impractical to use in corn fields (Messersmith 1975) and ineffective in forest nurseries (Rowe 1971), a raptor-mimicking kite suspended from a helium-filled balloon (hereafter called a kite-balloon or KB) has reportedly been successful in reducing bird damage in one Oregon grape vineyard since 1976 (D. Lett, pers. commun.). A similar device has reportedly reduced bird damage at one Washington grape vineyard by 70-80% (Woodburne 1979 and pers. commun.). Woodburne (1979) estimated that a single KB could protect 5-6 acres (2-2.4 ha) of grapes, whereas another recent report (Anon. 1979) estimated that four KB units would protect about 30 acres (12 ha) of vineyard area. However, none of these estimates of KB effectiveness was based on results from well-controlled, replicated experiments.

To better determine the effectiveness of KB devices for bird damage reduction, we conducted an intensive evaluation in one California wine grape vineyard in 1979 and more extensive, replicated tests at three other California grape vineyards in 1980. During 1981, we evaluated several kinds of balloons which are available for use in KB devices to determine their relative longevities and flight characteristics. This report summarizes our findings.

METHODS

Field Tests in Wine Grapes

Study Sites

A 1.1-ha vineyard (hereafter, the FIT vineyard), located in Vacaville, Solano County, California, and planted with Zinfandel wine grapes, was used for the KB evaluation in 1979. The three wine grape vineyards studied in 1980 were within 20 km of Calistoga, Napa County, California. Pinot noir was the variety grown at both the 1.8-ha UPT vineyard and the 3.9-ha PAR vineyard, whereas Zinfandel was grown at the 1.9-ha AMA vineyard. Each of the four vineyards included in these two tests was selected based on the relatively high (>10%) levels of bird damage recorded in recent years (Hothem, unpubl. data).

Treatment

During 1979 each "treatment" consisted of one KB tethered to a post near the center of the vineyard for 7 consecutive days. Each control period at the vineyard also consisted of 7 consecutive days during which no KB (NKB) or other damage control measure was used. The first 7-day evaluation period, a NKB period, began on July 30 when 10% of the vines located in the outermost row of the vineyard had at least one grape bunch with bird damage. This was followed by a treatment period and then alternate control and treatment periods until harvest (a total of six periods).

The KB tested in 1979 was made up of the same components that were marketed commercially as "kite hawks"[1] in 1979: (1) a blue, spherical weather balloon made of rubber (model AB5.5, WeatherMeasure

[1] Use of trade names does not imply endorsement of commercial products by the Federal Government.

1982. Proceedings Tenth Vertebrate Pest Conference
(R.E. Marsh, Ed.), Univ. of California, Davis, Calif.

Corp., Sacramento, CA) with a maximum inflation diameter of about 1.7 m (but, for the test, filled to a diameter of about 1.2 m, 0.9 m^3) and (2) a kite (Günther Flugspiele, W. Germany) with a 1.3-m wingspan and the full-color likeness of an immature golden eagle (Aquila chrysaetos) imprinted on its lower side. The balloon was tethered to a vineyard post with 30 m of dacron fishing line (59-kg-test). The kite was attached to the tether line at a point about midway between the ground and the balloon by cutting the line and attaching the ends to the upper and lower sides of the kite with fishing swivels.

The KB was placed in the vineyard within 1 h after sunrise on the first day of each 7-day treatment period and, to ensure that it was functioning properly, was checked and repaired or replaced as necessary each day between 0630 and 0730 h and between 1700 and 1800 h.

During 1980 KBs were deployed at each of the three vineyards at the rate of about one per hectare. In addition to the blue balloon used in 1979, we also used spherical white, orange, red, and yellow balloons (model AB5.5) and an orange tetroon, a tetrahedron-shaped balloon made of polyurethane (PT, Atmospheric Instrumentation Research, Inc., Boulder, CO) which had a maximum volume of 0.5 m^3.

Three kites made by Günther were used in 1980: (1) the eagle used in 1979, (2) a newer model golden eagle, with four circular holes in the leading edge of the wings, and (3) a plastic kite with a 0.76-m wingspan and the likeness of a falcon (Falco peregrinus) imprinted on its lower side. A fourth kite, a delta-shaped kite with a 1.65-m wingspan was used to a limited extent. This kite was supported by a wooden-dowel framework, and the blue body and wings and the white head and tail were made of polyester-and-cotton cloth sewn together to resemble an eagle.

For each KB, the balloon was tethered with 23-kg-test nylon line in lengths ranging from 16 to 60 m. One kite was attached each day at a different position on the tether line, from 8 to 52 m above the ground, and the location of the KB tether point (a vine post) was moved at least 25 m each day. Anchor points were selected at random with the only requirement being that no vine in the vineyard could be more than 70 m away from an anchor point. The type of kite and the type and color of the balloon for each KB device were also changed every 1-2 days. Each KB was checked at least twice daily to ensure that all components were functioning properly.

Although the KB components and their relative positions were varied regularly, we made no efforts to evaluate the separate effects of these factors. Our objectives were instead to try to reduce habituation of the birds to the devices and to determine only if the control concept -- i.e., exploitation of the birds' fear of raptors to frighten them away -- could reduce overall bird damage in the test vineyards.

Bird Damage Evaluation

Before the start of the first 7-day evaluation period in 1979, 40 groups of six adjacent vines (240 total vines) were selected at random for damage assessment. All of the vines, except one chosen at random from each group, were covered with bird-proof plastic netting. On the first day of the first 7-day period, five grape bunches were selected at random from each of the 40 uncovered vines using the method of DeHaven and Hothem (1979). Each bunch was returned to zero bird damage by removing any damaged grapes and then marked with a numbered spring clothespin attached to the peduncle. At the start of each subsequent 7-day evaluation period, the netting was removed from one additional vine selected at random in each of the 40 groups, and the procedure was repeated.

At the end of each 7-day period, an observer visually examined the 200 pre-selected grape bunches for that period and estimated the percentage of berries damaged (pecked or removed) by birds. Each bunch was then assigned a damage rating from an 11-integer scale. This scale was derived by selecting percentage steps which, when transformed by the arcsine transformation, resulted in a series of integers (Little and Hills 1978: 162-165, DeHaven and Hothem 1979). The ratings and their corresponding percentage bird loss values were: 0=0%, 1=2.5%, 2=10%, 3=21%, 4=35%, 5=50%, 6=65%, 7=79%, 8=90%, 9=97.5%, and 10=100%. For each of the six evaluation periods, the individual bunch ratings were averaged to obtain a mean damage rating for the vineyard. The mean damage ratings for the first five evaluation periods, when some vines were still protected with netting, and were thus unavailable to birds, were multiplied by the percentage of fines that were uncovered during each period so all six periods would be directly comparable. The mean damage ratings were then backtransformed to percentage losses. The effectiveness of the KB was estimated by comparing the average percentage bird damage during the three KB periods with that for the three NKB periods for several distances from the KB anchor point.

In 1980 the procedures we used were the same as in 1979 except that: (1) damage during each period was evaluated on 50 instead of 40 vines, (2) the same vines (but different random bunches returned to zero damage) were used for two consecutive evaluation periods at one of the vineyards (AMA), (3) damage assessments consisted of counts of the actual number of grapes damaged by birds, and (4) the weight of the berries destroyed and the percentage loss during each evaluation period were both estimated. The estimates of loss in terms of weight for each 7-day period at each vineyard were based on: (1) the actual number of vines in the vineyard, (2) the estimated number of bunches per vine, based on bunch counts made on 50 vines used for one of the damage assessments, (3) the estimated number of berries per bunch, based on berry counts made on 50 bunches, one per assessed vine, during the final damage assessment, (4) the estimated berry weight, based on the weights of two random berries per bunch from each of the 50 bunches selected for berry counting, and (5) the estimated number of damaged berries per bunch. Effectiveness of the KB was estimated by comparing the average bird damage during the KB versus the NKB periods.

Bird Population Evaluation

In 1979 a bird count was conducted each day, except the first day of each evaluation period. Each count was conducted within 2 h after sunrise and comprised (1) a 10-min station count from each of the vineyard's four corners and (2) a count from two transects. During each station count, an observer recorded all birds that entered one side of the vineyard; the order of the station counts was selected at random each day. Following the station counts, the observer conducted two transect counts, one in a north-south direction and the other east-west, using randomly selected vineyard rows. An observer walked each transect and recorded both the number of birds, by species, which flushed from the vines and the time required to complete the transect. The station and transect data were then converted to birds per minute.

In 1980 two bird counts were conducted on separate days during each 7-day evaluation period at each vineyard. Each count was conducted within 3 h after sunrise, beginning from two stations located at diagonally opposite vineyard corners. From the stations, the four borders of the vineyard were recorded. Two transects were then completed as in 1979. The station and transect data were then converted to birds per minute.

Balloon Evaluation

Study Site

The longevity and flight characteristics of several balloons used in KBs were evaluated in a 1.2-ha open, grassy field on the campus of the University of California at Davis, Solano County, California. This site was chosen because of its proximity to our office and because its weather conditions are similar to those of nearby grape-growing areas.

Longevity Evaluation

Four balloons currently used or available for use in KB devices were tested: (1) the AB5.5, the spherical rubber balloon used in the field tests (blue, yellow, and white), (2) a second spherical rubber balloon, model AB4 (WeatherMeasure Corp., Sacramento, CA) with a maximum inflation diameter of 1.2 m (0.9 m^3) (white only), (3) an orange PT, and (4) a reddish-orange tetroon made of mylar (Raven Industries, Inc., Sioux Falls, SD) with a maximum inflation volume of 1 m^3. Two levels of inflation were tested for each of the spherical balloons; the AB4s were inflated to 0.40^3 and 0.68 m^3 and the AB5.5s to 0.54 m^3 and 0.95 m^3. The tetroons were inflated until their sides were barely taut.

The first of two tests was conducted from 4 to 10 August when all of the various balloons were deployed; during a second test, from 18 to 28 August, only the AB5.5s (all three colors at both inflation levels) and the PT were evaluated. Each balloon was attached to a 21-m-long, 45-kg-test nylon line with snap swivels on each end and sent aloft immediately after inflation where it remained until it became inoperable (i.e., would no longer stay aloft, even with additional helium). Each balloon tether was attached to a stake, and all stakes were far enough apart in the test field to prevent line entanglements and balloon collisions.

During four daily checks, at about 0630, 1200, 1500, and 2130 h, we recorded the condition of each balloon (aloft, inflated but not aloft, or inoperable) and the weather conditions (wind speed and direction and ambient air temperature). When a balloon was down but undamaged, sufficient helium was added to send it aloft.

The total time each balloon was aloft before becoming inoperable (from initial inflation to the last daily dheck when still operable) was compared by using a one-way analysis of variance (ANOVA). In addition, a three-way ANOVA was used to evaluate the effects of color, inflation level, and test period on longevity of the AB5.5s.

Flight Characteristics Evaluation

During the second test, three variables were recorded for one PT and two AB5.5s (one filled with 0.54 m^3 of helium and the other with 0.95 m^3) to estimate the effects of wind on balloon flight: (1) the minimum angle of inclination between the tether line and the ground during a 30-s period (an indirect measure of the balloon's distance above the ground), (2) the range of angle of inclination during the 30-s period (an indirect measure of vertical movement of the balloon), and (3) the range of the horizontal arc subtended by the tether line during a 30-s period (a measure of the balloon's horizontal movement). These variables were measured with a protractor for each of the three balloons during the first seven regular balloon checks after inflation on day 1, and an ANOVA designed for repeated measures on the same subjects (Bruning and Kintz 1977) was used to analyze the flight characteristic data.

RESULTS AND DISCUSSION

1979 KB Test

When all of the assessed vines during all six evaluation periods were included, there appeared to be no difference in the average percentage loss during the treatment compared with the control periods (2.8 vs. 2.9%, Table 1). However, from 19% of the assessed vines, the view of the KB was obstructed by trees. If the data from these obstructed vines are deleted, then the average loss during the three treatment periods (1.8%) was 33% less than the average recorded during the control periods (2.7%).

Table 1. Estimated percentage loss of grapes to birds for each 7-day evaluation period during an evaluation of a KB device in a California wine grape vineyard during 1979.

Evaluation period[a]	Percent loss based on distance from KB anchor point						
	24(0.2)[b]	42(0.6)	61(1.2)	80(2.0)	99(3.1)[c]	All obscured vines[d]	All assessed vines
NKB1	3.9	2.8	4.0	4.2	4.2	3.3	4.0
KB1	0.6	0.5	2.0	1.9	1.9	1.4	1.8
NKB2	0.8	1.2	1.5	2.4	2.4	5.6	3.1
KB2	0.2	0.7	1.9	2.0	2.0	14.4	3.7
NKB3	1.3	1.5	1.4	1.4	1.4	3.1	1.6
KB3	0.2	0.5	1.2	1.6	1.5	19.0	3.0
Overall Ave. % Loss:							
NKB	2.0	1.8	2.3	2.7	2.7	4.0	2.9
KB	0.3	0.6	1.7	1.8	1.8	11.6	2.8
% Reduction	85	67	26	33	33	+190	2

[a] NKB = No kite-balloon period; KB = Kite-balloon period.

[b] Distance from the KB anchor point (m); area of the circle around KB anchor point in parentheses (ha).

[c] All assessed vines minus obscured vines.

[d] Vines where birds' view of KB was obscured by trees (not included in previous data).

Damage levels during all periods tended to increase with distance from the KB tether post, whereas the percentage reduction in damage apparently attributable to the KB decreased from a high of 85% for the 0.2-ha area immediately surrounding the KB to 33% for the entire vineyard (Table 1).

Except for the vines obstructed by trees, the percentage loss recorded during the first control period (NKB-1) was greater than that for any subsequent period (Table 1). The first exposure to the KB may have thus reduced bird feeding activity during the remainder of the damage season, a possibility that is also suggested by the bird count data. The number of birds per count during the second through sixth evaluation periods was about half (40%) of the number recorded during NKB-1 (Table 2). Thus, a number of birds evidently left the vineyard area as a result of the initial deployment of the KB. In addition, there was at least a partial shift in feeding activity to vines from which there was an obscured view of the KB and where birds may have felt protected by cover.

Table 2. Average numbers of birds per minute recorded during counts in four California wine grape vineyards during tests of KB devices in 1979 and 1980.

Evaluation period[a]	Birds/min/vineyard			
	FIT	AMA	PAR	UPT
NKB1	1.07	0.09	1.48	2.09
KB1	0.58	0.04	0.74	0.37
NKB2	0.71	0.75	2.33	2.37[b]
KB2	0.69	0.05	1.65	-
NKB3	0.50	0.33	0.83[b]	-
KB3	0.40	0.12	-	-
Overall ave. birds/min:				
NKB	0.77	0.40	1.55	2.23
KB	0.56	0.07	1.20	0.37
% reduction	27	82	23	83

[a] NKB=No kite-balloon period; KB=Kite-balloon period

[b] Last evaluation period completed before harvest.

Although the one KB combination appeared to remain effective during the 6-wk period for the area <42 m from the anchor point, little or no reduction in bird damage was recorded for the area ≥61 m from the anchor point during the final pair of evaluation periods (NKB-3 and KB-3). Apparently, the birds had become sufficiently habituated to the KB by the third week it was deployed that its effectiveness was reduced.

Overall, the trend in the numbers of grape-damaging birds recorded during each evaluation period was similar to the trend of bird damage levels of the unobstructed vines; 27% fewer birds were recorded during KB than NKB periods (Table 2). Black-headed grosbeaks (Pheucticus melanocephalus) made up of 43% of the 17 species of birds identified in 1979, almost three times more than the California quail (Lophortyx californicus), the second-most frequently counted species (Table 3).

Table 3. Percentages of total identified bird species during tests of KB devices in four California wine grape vineyards during 1979 and 1980.

Bird Species	Vineyard FIT %	AMA %	PAR %	UPT %
House finch (Carpodacus mexicanus)	4.6	6.9	10.2	93.9
California quail (Lophortyx californicus)	15.5	0.0	39.4	0.0
Starling (Sturnus vulgaris)	<0.1	57.3	1.5	0.0
Black-headed grosbeak (Pheucticus melanocephalus)	43.2	0.0	0.2	0.0
American robin (Turdus migratorius)	4.6	0.0	21.8	0.2
Western bluebird (Sialia mexicana)	0.0	0.0	15.1	1.0
Sparrow spp.	0.5	23.7	0.2	0.0
Scrub jay (Aphelocoma coerulescens)	12.5	0.0	0.7	0.0
Western tanager (Piranga ludoviciana)	9.7	0.0	0.3	0.5
Others (no. species identified)	9.4(8)	12.1(3)	10.6(8)	4.4(2)
TOTAL (no. species)	100.0(16)	100.0(6)	100.0(17)	100.0(6)

1980 KB Test

For the three vineyards, both the average percentage loss and the weight loss of grapes to birds ranged from 32 to 88% less during the KB periods than during the NKB periods; the average reduction was 48% (Table 4). In only two instances were estimated damage levels greater during a KB period than during the immediately preceding NKB period, but both times the apparent increase was small (0.04 - 0.08 percentage points, Table 4).

The results of the bird counts also indicate a definite KB treatment effect. With only one exception (the third NKB period at the PAR vineyard), at each vineyard the number of birds per minute was lower for each KB period than for the preceding and following NKB periods (Table 2). The average percentage reductions in bird numbers during KB compared with NKB periods (23-83%) were similar to the damage level reductions.

The wide range of effectiveness recorded for the KBs at the test vineyards could be related to a variety of factors, including the possible differential effectiveness of the KB when used to frighten various species of grape-damaging birds (Conover 1982). Bird count results indicated that the numbers of some species of birds were reduced during KB periods while others were not affected or possibly increased in numbers. The average number of house finches (Carpodacus mexicanus) per minute, for example, was reduced by 87-100% during the KB periods compared with the NKB periods at the three vineyards. At the PAR vineyard, where 17 grape-damaging species were recorded, the average number of California quail per minute was also reduced by 87% during the KB periods; however, the numbers of western bluebirds (Sialia mexicana) and American robins (Turdus migratorius) counted per minute both increased during the KB periods, by 92 and 20% respectively. The apparent species-specific effectiveness of the KB, coupled with the diverse species composition recorded at each vineyard (Table 3), was probably responsible for at least part of the KB's rather wide range of effectiveness among vineyards.

Table 4. Estimated percentage loss and absolute loss of grapes to birds for each evaluation period during a test of KB devices in three California wine grape vineyards during 1980.

Evaluation period[a]	Percent and absolute loss (kg/ha) per vineyard[b] AMA	PAR	UPT	Ave. % and absolute loss (kg/ha) per period
NKB1	0.53 (32.2)	0.26 (14.4)	1.92 (87.6)	0.90 (44.7)
KB1	0.57 (34.3)	0.34 (18.4)	0.16 (7.1)	0.36 (19.9)
NKB2	1.21 (73.3)	0.83 (45.3)	0.59[c] (27.2)	0.88 (48.6)
KB2	0.82 (49.7)	0.23 (12.3)	- -	0.52 (31.0)
NKB3	1.27 (77.0)	0.46[c] (25.3)	- -	0.86 (51.2)
KB3	0.65[c] (39.4)	- -	- -	0.65 (39.4)
Overall ave. % and absolute loss (kg/ha) per vineyard:				
NKB	1.00 (60.8)	0.52 (28.3)	1.26 (57.4)	0.88[d] (47.8)
KB	0.68 (41.1)	0.28 (15.4)	0.16 (7.1)	0.46[d] (26.9)
% Reduction	32 (32)	46 (46)	88 (88)	48[d] (44)

[a]NKB=No kite-balloon period; KB=Kite-balloon period.

[b]Estimated percent loss= $\sum_{i=1}^{50} M_i \bar{Y}_i / \bar{X} \cdot \Sigma M_i$; Estimated absolute loss= $N(\sum_{i=1}^{50} M_i \bar{Y}_i / 50)(\bar{Z})$; M_i=Number of bunches on ith vine; $\bar{Y}_i$=Average number damaged berries/bunch on ith vine; $\bar{X}$=Average total number berries/bunch; N=Total vines in vineyard; $\bar{Z}$=Average berry weight.

[c]Last evaluation before harvest.

[d]Weighted means.

General Observations, 1979-1980

The balloon was the most costly of all the KB components, with retail costs in 1981 ranging from $16 for each AB5.5 to $35 for each PT. The cost to inflate each balloon with helium, which cost $7.80/m^3 in 1981, ranged from $3.90 for a PT to $7.41 for an AB5.5 (at the maximum tested inflation level).

The average longevity of the AB5.5s ranged from 2.0 days in the 1979 grape test to 5.3 days in a test in an Arizona lettuce field in November 1980 (DeHaven, unpubl. data). Weather conditions in Arizona, which were at least partly responsible for the increased longevity in the lettuce test, included: (1) generally lower wind velocities (<3 km/h), (2) lower average daily temperature range (by 2-3°C), (3) lower average daily maximum temperature (by 2-3°), and (4) reduced daily exposure to degrading UV light (related to the shorter day length in November compared with August and September when the grape test was conducted).

In general, the PTs retained helium better than the AB5.5s and, during the 1980 grape test, they lasted an average of 5.5 days each. The PT functioned well on calm days but was usually blown down into the vines and punctured when the wind velocity exceeded about 8 km/h. Although minor repairs were easily made with tape, this approach became impractical when the PTs were badly damaged during prolonged windy periods.

The kites cost $2-7 each, and they usually lasted 7-14 days when they were fully reinforced at the primary stress points. Irreparable damage to the kites usually occurred when high winds (>8 km/h) caused kites to collide with the ground, vegetation, and grape-vine trellises.

Balloon Longevity Evaluation

The average longevity of the PT was 7.1 days, significantly greater ($p < 0.05$) than that of the other nine balloon treatments tested. The longevities of the yellow AB5.5 (3.1 days) and white AB5.5 (3.2 days), both at low levels of inflation, were significantly shorter than that of the PT, but they were significantly greater ($P<0.05$) than the various other balloon treatments which had average longevities ranging from 0.9 to 1.9 days.

The longevity of the mylar tetroon (1.3 days) was shorter than the PT and the low-inflation yellow and white AB5.5s. Shortly after its initial deployment, each mylar tetroon developed several 2-cm-long cracks along creases created when the tetroon was folded for shipment. These cracks allowed helium to escape at a rapid rate, greatly shortening the tetroon's longevity.

The average longevity for all yellow AB5.5s (2.5 days) was significantly greater, and the average longevity for all blue balloons (1.5 days) was significantly less than the overall average. The average longevity of all white balloons (2.0 days), however, was neither significantly greater than the blue nor less than the yellow. The longevity of balloons at high levels of inflation (1.4 days) was significantly shorter than that of balloons at low levels (2.7 days), but no significant interaction between level of inflation and balloon color was detected. Longevity did not differ significantly during the two test periods, even though the average maximum air temperature during the first test period was about 8°C higher and the average wind speed about 4 km/h lower than during the second period. Although both high winds and high temperatures have previously appeared to cause decreased balloon longevity, no precise correlations of these factors were possible from these tests.

Flight Characteristics Evaluation

As observed in 1980, the PT "flew" much closer to the ground than either of the spherical balloons. At wind velocities $\geq$ 8 km/h the PT only maintained an average altitude of 4 m, compared with 13 and 17 m, respectively, for the low-and high-inflation AB5.5s. The average minimum angles of inclination for the three balloons tested were significantly different ($p < 0.001$); the high-inflation AB5.5 flew highest (58°) followed by the low-inflation AB5.5 (45°), and the PT (21°).

The amount of vertical movement did not differ significantly among the three balloons ($p > 0.20$). However, the low-inflation AB5.5 had significantly greater horizontal movement (36°) than either the high-inflation AB5.5 (26°) or the PT (20°) ($p < 0.05$).

Knowledge of each balloon's flight characteristics and longevity are important in deciding which balloon should be used in a particular location. However, such knowledge must be combined with as yet undetermined data on individual kite movements and the effectiveness of various kite and balloon combinations for frightening various species of birds.

CONCLUSIONS AND RECOMMENDATIONS

Although several other investigators have found various combinations of raptor-silhouettes and balloons to be ineffective for reducing damage by birds (Meylan and Murbach 1977, Rowe 1971, Messersmith 1975), our tests indicated that KBs deployed for 1 wk at a rate of about one per ha of grape vineyard, reduced bird damage compared with 1-wk periods when no KBs were deployed.

One problem is keeping the balloons aloft. Although KBs are apparently more effective during a light wind than during calm conditions (Conover 1979), winds greater than about 8 km/h blow tetroons very near the ground. This would probably increase the risk of damage to the KB while reducing the KB's range of effectiveness. The spherical balloons, although more aerodynamically stable in high winds, tend to become inoperable after only a few days. Their longevity might be increased if they were placed in a sheltered location at night or at other times when birds were not a threat and when weather conditions were most severe.

If KBs are used for extended periods, birds may become habituated to them, and their effectiveness may be reduced. According to Shalter (1978), "the relative lack of habituation to recurring predators in nature is, in part, a function of their ever-changing spatial relationships relative to the inanimate environment. He demonstrated that habituation by birds could be reduced by periodically changing the location of the model predator. We did not change the types of kite or balloon components or their locations during the 1979 test, and the grape-damaging birds appeared to habituate to the device. The results from the 1980 test, however, indicate that we successfully reduced habituation by regularly changing the kite and balloon models and their relative and absolute heights above the ground and by changing the locations of the KBs in the vineyard.

Other possible means of improving the effectiveness of KBs include: (1) the use of a kite which mimics a bird of prey common within the range of the pest species (Inglis 1980), (2) the presentation of the KB as infrequently as possible, perhaps only during times of the day when birds are feeding (Slater 1980), (3) the incorporation of alarm or mobbing calls of the pest species (Inglis 1980), (4) the reinforcement of threat by supplemental devices such as a gunshot or the presence of a human (Slater 1980), (5) the use of a live predatory bird to enhance the response to the kites (Inglis 1980), and (6) the use of alternate bird scarers, using KBs for perhaps only 5-7 days followed by conventional devices for a few days before the KBs are deployed again (Kimber 1963).

Since the effectiveness of the KBs is apparently species-specific, further study is needed to determine which combination of kites and balloons is most effective against each of the major depredating species of birds. In addition, the range and duration of the KBs' effectiveness should also be determined for each species under various conditions. Such data should be gathered during whole-season tests on entire grape vineyards so that the actual cost-effectiveness of the KBs can be determined. Eventually, the effectiveness of KBs when used as part of an integrated pest management program should be evaluated.

ACKNOWLEDGMENTS

We greatly appreciate the assistance of the following who helped with various aspects of one or more of the tests: T. Akesson, D. Antonius, T. McAuley, R. Nakamoto, D. Otis, K. Rankin, J. Skorupa, and M. Tobin, U.S. Fish and Wildlife Service; and M. Rowe and M. Miller, University of California at Davis. We also thank the grape-growers, S. Amato, W. Fitch, K. Parr, J. Upton, and S. Upton for their cooperation and for allowing us to use their vineyards, and T. Kawakami for providing us access to the balloon study site. We appreciate the efforts of J. Glahn, D. Mott, M. Saiki, and M. Tobin who reviewed various drafts of this manuscript.

LITERATURE CITED

ANONYMOUS. 1979. Weather balloons, plastic hawk kites team to help reduce bird damage for cherry, grape growers. Goodfruit Grower. March 1, 1979, p. 27.

BLOKPOEL, H. 1976. Bird hazards to aircraft. Books Canada, Inc., Buffalo, N.Y. 236 pp.

BROWN, R.G.B. 1974. Bird damage to fruit crops in the Niagra Peninsula. Can. Wildl. Serv. Rep. Ser. No. 27. 57 pp.

BRUNING, J.L., and B.L. KINTZ. 1977. Computational handbook of statistics. Scott, Foresman and Co., Glenview, Ill. 308 pp.

CONOVER, M.R. 1979. Response of birds to raptor models. Proc. Bird Control Seminar, Bowling Green State Univ., Bowling Green, Ohio, 8:16-24.

__________. 1982. Behavioral techniques to reduce bird damage to blueberries: methiocarb and a hawk-kite. Wildl. Soc. Bull. 10:In Press.

CRASE, F.T., C.P. STONE, R.W. DEHAVEN, and D.F. MOTT. 1976. Bird damage to grapes in the United States with emphasis on California. U.S. Dep. Inter., Fish and Wildl. Serv. Spec. Sci. Rep. Wildl. 197, 18 pp.

DAVIDS, R.C. 1960. How would you scare them off? Farm J. 84(9):27, 64-66.

DAVIS, P.J. 1974. Fundamentals of bird scaring--a laboratory approach. Proc. Assoc. Appl. Biol. 76:353-358.

DEHAVEN, R.W., and R.L. HOTHEM. 1979. Procedure for visually estimating bird damage to grapes. Pages 198-204 in J.R. Beck, ed. Vertebrate Pest Control and Management Materials, ASTM STP 680. American Society for Testing and Materials, Philadelphia.

FEARE, C.J. 1974. Ecological studies of the rook (Corvus frugilegus L.) in north-east Scotland. Damage and its control. J. Appl. Ecol. 11:897-913.

INGLIS, I.R. 1980. Visual bird scarers: an ethological approach. Pages 121-143 in E.N. Wright, I.R. Inglis, and C.J. Feare, eds. Bird problems in agriculture. BCPC Publ., Croydon, England.

KIMBER, D.S. 1963. Use of balloons as bird scarers in field trials. Natl. Assoc. Adv. Sci. Q. Rev. XV. 61:40-41.

LITTLE, T.M., and F.J. HILLS. 1978. Agricultural experimentation, design, and analysis. John Wiley and Sons, New York. 350 pp.

MESSERSMITH, D.H. 1975. Bird depredation control. Atl. Nat. 30:110-114.

MEYLAN, A., and R. MURBACH. 1966. Versuch zum Schutz einer Sonnenblumerpflanzung gegen Grunfinken (Carduelis chloris) mit Raubvogelattrappen. Ornithologischer Beo Bachter 63:74-76.

ROWE, J.J. 1971. Prevention of damage by birds and mammals in forest nurseries. Q. J. For. 65:148-157.

SHALTER, M.D. 1978. Effect of spatial context on the mobbing reaction of pied flycatchers to a predator model. Anim. Behav. 26:1219-1221.

SLATER, P.J.B. 1980. Bird behavior and scaring by sounds. Pages 105-114 in E.N. Wright, I.R. Inglis, and C.J. Feare, eds. Bird problems in agriculture. BCPC Publ. Croydon, England.

WOODBURNE, L.S. 1979. Kite-balloon scares birds. WinesVines 60(4):36.